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13. ABSTRACT (Maximum 200 words)

Research continues in the areas of video storage and processing.

In the area of video storage, work is continuing on strategies for placement and retrieval of Variable Bit Rate (VBR) video on parallel disk arrays.

In the area of video processing, the emphasis has been on algorithms for video resolution enhancement.

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Summary of Activities for 6/1/1994 through 5/31/95

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During the past year, we continued our efforts in the areas of video storage and processing [3].

1 Video Placement and Retrieval Strategies

In the area of video storage, we are continuing our work on strategies for placement and retrieval of Variable Bit Rate (VBR) video on parallel disk arrays. We choose a parallel disk array as our storage medium, as disk arrays have been shown to provide cost-effective storage and high-bandwidth transfer capabilities and are becoming popular in video-on-demand systems. For storage efficiency we compress the data before writing to disk. Since there are several different modes of encoding, a major question to address is the type of rate control mechanism, if any, that is going to be applied in generating the compressed bit stream. One option would be to generate a truly VBR, constant quality stream without any rate control, buffers or quantization feedback. Another possibility is to generate a Pseudo Constant Bit Rate (PCBR) stream in which quantization feedback is applied to implement the leaky bucket rate control mechanism in order to avoid buffer overflow or underflow.

It is generally believed that video inherently results in variable bit rate data and as such, the main advantage of true VBR over PCBR is its true constant quality. As a result, in using CBR, either the quality of the video varies with time, or, in order to avoid nonuniform quality, the CBR bandwidth is chosen at such a high level so as to ensure the quality remains above a certain threshold at high motion parts of the video sequence. This latter approach results in overallocation of storage resources in storing CBR data. Since it has been shown that typical VBR video may have a peak to mean

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ratio of 3:1, it is conceivable to achieve the same quality of video at about 1/3 of the cost, by storing VBR rather than CBR video data on disks. Therefore, the same statistical multiplexing ideas that have traditionally been used in networking applications can be exploited to reduce the cost per stream in video storage applications. There is however, one major difference between networking and storage applications in that unlike the networking applications, in the storage scenario, one can exploit the a priori knowledge of the video bit trace in order to optimize both the data placement algorithms and the admission control algorithms.

The choice of true VBR versus CBR also influences the data units in which the compressed bit stream is stored on the disks. In our previous work [1], we have presented an efficient placement strategy for CBR video based on this round-robin servicing. Specifically, we have shown that for fixed-rate data, an optimum disk read unit size may be found by considering timing and buffer constraints [1].

For VBR data, the block sizes to be written to and read from the disk can not be chosen as easily as for CBR data. The basic issue is whether to conform to the equal playback duration specified by the length of the service round, or to disregard the variable playback consumption and store the data in equal-sized blocks. We call the first method Constant Time Length (CTL) data placement, and the second method Constant Data Length (CDL).

CTL data placement is characterized as having variable data length blocks with constant real-time playback duration. The sum of the data lengths of simultaneous user requests is therefore also variable; thus there is a nonzero probability that this sum exceeds the disk read capacity, resulting in incomplete or missed reads.

Each CTL-stored video has a unique pattern of data block lengths that may be derived from the video bit trace and the length of the service round. Because data blocks may be interleaved across many disks [1], the stored blocks may not be contiguous. In this case, replacing or editing the video will result in disk fragmentation problems. To avoid this, we examine the possibility of storing CDL blocks. Past approaches have focused on reading a variable number of of blocks per service round. We do not consider this model because it results in excessive disk seeks, possibly reducing the system disk efficiency. Instead, we consider a system that uses extra buffer to smooth out the variations in the playback rate while reading data from the disk at a constant rate, one CDL block per service round. Because the total disk

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read and seek time is a function of the number of users, we can prevent disk service time overload by simply limiting the number of users. Our primary concern in this system is therefore buffer overflow.

To ensure that the system resources are not overallocated when too many users request data simultaneously, we require admission control algorithms. So far, we have considered two types of admission control: statistical and deterministic. We briefly describe the two strategies here before fully analyzing them in conjunction with the data placement policies. A statistical admission control exploits the bit rate statistics of the videos on the disk. The advantage of such a strategy over network admission control schemes is that it uses the actual histogram of the data to be read rather than generic video statistics for all possible video sequences. Alternatively, we can apply a deterministic admission control strategy by exploiting the specific knowledge of the bit traces of requested videos. Since the disk system has full knowledge of the future bit rate traces needed to service all user requests, we can decide if the admission of a new request will cause a system overflow during the length of the request.

Our work is currenty focusd on investigating the properties of statistical and deterministic admission control together with these placement strategies analytically and verify them using both simulations and experiments. In doing so, we evaluate and compare the performance of the data placement techniques and admissions control strategies with respect to the level of interactivity, delay, buffer usage, and overload probability.

2 Video Resolution Enhancement

In the area of video processing, our emphasis has been on algorithms for video resolution enhancement. The basic idea is to use multiple frames of a video sequence to enhance the spatial resolution of each frame. This problem has potential impact in video printing applications in which a high resolution version of only *one* frame is needed for viewing and/or priting. Our approach has been to partition the problem into two parts: (a) subpixel accuracy motion estimation (b) iterative merging/reconstruction. Since there is currently an abundance of iterative reconstruction algorithms in the literature, our efforts so far has been on subpixel motion estimation problem. Our approach has been to exploit the color, as well as the luminance information to derive

the motion field. This has resulted in significant improvement of motion field estimation. Our next step is to analytically derive an upper bound on motion estimation accuracy of frames obtained with finite aperture cameras. Once the motion estimation algorithms have been developed, we plan to test our approach on real life video sequences.

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[1] E. Chang and A. Zakhor, "Scalable Video Data Placement" to be presented at the SPIE Electronic Imaging Symposium, San Jose, CA, Feb. 1994.

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[3] Ed Chang and Avideh Zakhor, "Admissions Control and Data Placement for VBR Video Servers," Proceedings of International Conference on Image Processing, November 1994, Austin, Texas, Vol. 1, pp. 278-282